Phthalates

General Information

Phthalates are industrial chemicals added to many consumer products, including vinyl flooring adhesives; detergents; lubricating oils; solvents; food packaging; automotive plastics; plastic clothing, such as raincoats; and personal-care products, such as soap, shampoo, hair spray, and nail polish. Phthalates are widely used in flexible polyvinyl chloride plastics, such as plastic bags, food packaging, garden hoses, inflatable recreational toys, blood-storage containers, intravenous tubing, children's toys, and some pharmaceutical and pesticide formulations. Soil and water contamination are greatest in areas of industrial use and waste disposal.

People are exposed through direct contact with products that use phthalates or through food in contact with packaging that contains phthalates. The different phthalates vary in their ability to produce the following effects in animal studies: testicular injury, liver injury, liver cancer, anti-androgenic activity, teratogenicity, and peroxisomal proliferation. For example, di-2-ethylhexyl phthalate, benzylbutyl phthalate, dibutyl phthalates, and di-isononyl phthalate have reproductive effects in animal studies. Greater susceptibility to reproductive toxicity at lower doses occurs for *in utero* exposures or in younger animals. Peroxisomal proliferation may be a pathway to the development of liver cancers in animals. However, there is debate as to whether peroxisomal proliferation is relevant in people (Melnick, 2001) because of differing metabolic pathways in people. Effects of phthalates in people have not been well studied.

For several phthalates, it is suspected that the monoester metabolite may mediate toxic effects. Table 61 shows the relation between some phthalates and their monoester metabolites and also includes their commonly used abbreviations. The Center for the Evaluation of Risks to Human Reproduction of the NTP has recently reviewed the reproductive effects for many of the phthalates (see http://cerhr.niehs.nih.gov/news/). Not all the different phthalates have been reviewed by government agencies. Information about external exposure (environmental levels) and health effects is also available for some of the phthalates from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urinary Phthalate Metabolite Levels Reported in the Tables

Urine levels of phthalate metabolites were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Results are presented in Tables 62-75. The amount of monoester metabolite in the urine for each phthalate is a fraction of the total excreted urinary metabolites (about one fourth in the case of di-2-ethylhexyl phthalate), and the total amount of all metabolites in the urine is a fraction of the internal dose (Dirven et al., 1993). In the case of di-2-ethylhexyl phthalate, the amount of its monoester metabolite in urine represents roughly one tenth of the ingested dose during the previous 24 hours. It is not clear whether the monoester metabolite of a phthalate is produced to the same extent by differing routes of exposure (Liss et al., 1985; Peck

Table 61. Phthalates and their metabolites

Phthalate name (CAS number)	Abbreviation	Urinary metabolite (CAS number)
Diethyl phthalate (84-66-2)	DEP	Mono-ethyl phthalate (2306-33-4)
Dibutyl phthalates (84-74-2)	DBP	Mono-butyl phthalates (131-70-4) (mono-iso-butyl and mono-n-butyl)
Benzylbutyl phthalate (85-68-7)	BzBP	Mono-benzyl phthalate (2528-16-7) (some mono-butyl phthalate)
Dicyclohexyl phthalate (84-61-7)	DCHP	Mono-cyclohexyl phthalate (7517-36-4)
Di-2-ethylhexyl phthalate (117-81-7)	DEHP	Mono-2-ethylhexyl phthalate (4376-20-9)
Di-n-octyl phthalate (117-84-0)	DOP	Mono-n-octyl phthalate (5393-19-1)
Di-isononyl phthalate (28553-12-0)	DINP	Mono-isononyl phthalate

and Albro, 1982). There is variation from person to person in the proportions or amounts of the metabolite excreted after receiving similar doses (Anderson et al., 2001). In addition, there is modest variation from day to day in the amounts excreted for any individual (Hoppin et al., 2002).

The rank order of concentrations for the monoester metabolites of the various phthalates in this NHANES 1999-2000 subsample is similar to those in a previous study using a non-random subsample from NHANES III specimens (Blount et al., 2000). Di-2-ethylhexyl phthalate is the most widely used and studied of the various phthalates. However, mono-ethyl phthalate, mono-butyl phthalate, and mono-benzyl phthalate have higher urinary concentrations than mono-2-ethylhexyl phthalate. Such differences in the excretion of various phthalates may be due to differences in either exposure or toxicokinetics. For example, the higher levels of these particular phthalate metabolites may also be due to a greater fraction of the internal dose being converted to monoester phthalates; to a lesser conversion of these monoester phthalates to other products; or to greater accumulation from longer residence times, although the half-lives of phthalates are generally short. Several investigations have shown that two other metabolites of DEHP, mono-(2-ethyl-5-oxohexyl) phthalate and mono-(2-ethyl-5-hydroxyhexyl) phthalate, are produced at a threefold to tenfold greater extent than MEHP (Dirven et al., 1993; Peck and Albro, 1982).
The low detection rates for some of the long alkyl chain phthalates (di-isononyl- and dioctyl-) metablolites may be due to significantly less metabolism to the monoester metabolite as has been seen in animal studies. Diethyl-, dibutyl-, and benzylbutyl phthalates are contained to a greater extent in cosmetics, sundries, glues and adhesives than is di-2-ethylhexyl phthalate, and urine levels may reflect higher daily contact with those products or a greater extent of metabolism to these metabolites.

In this *Report*, there are several notable differences in concentrations for specific phthalate metabolites in regard to age, gender, and race/ethnicity. It is unknown whether such differences reflect differences in exposure, body-size relationships, or metabolism. Finding a measurable amount of one or more phthalate metabolites in urine does not mean that the level of one or more of these causes an adverse health effect. Measuring phthalate metabolites at these levels in urine is possible because of advances in analytical chemistry. Whether these levels of phthalate metabolites are a cause for health concern is not yet known; more research is needed. These levels of phthalate metabolites in urine provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of phthalates than those found in the general population. These data will also help scientists plan and conduct research on phthalate exposure and health effects.

Mono-ethyl phthalate

CAS No. 2306-33-4

Metabolite of diethyl phthalate
CAS No. 84-66-2

Diethyl phthalate is an industrial solvent used in many consumer products, particularly those containing fragrances. Products that may contain diethyl phthalate include perfume, cologne, deodorant, soap, shampoo, and hand lotion. People exposed to diethyl phthalate will excrete mono-ethyl phthalate in their urine. The amount of mono-ethyl phthalate is an indicator of how much contact with diethyl phthalate has occurred. Workplace air standards for external exposure have been established (ACGIH) or recommended (NIOSH) for diethyl phthalate. Generally, diethyl phthalate has low acute toxicity. It has not been completely classified with respect to its carcinogenicity (U.S. EPA, IARC, NTP). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported in Table 62 are similar or slightly lower than those reported in a non-random subsample from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared

Table 62. Mono-ethyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	179 (159-201)	28.9 (23.6-34.2)	61.4 (54.0-69.7)	164 (142-192)	450 (378-523)	1260 (988-1490)	2840 (2020-4070)	2536
Age group								
6-11 years	91.3 (73.0-114)	27.2 (20.4-35.7)	40.8 (35.9-46.8)	74.7 (50.6-107)	197 (129-259)	378 (290-644)	756 (379-1070)	328
12-19 years	211 (167-266)	32.7 (22.4-50.6)	72.4 (53.6-99.8)	193 (141-256)	558 (432-806)	1510 (1060-2100)	3260 (1670-4100)	752
20 years and older	190 (168-214)	27.7 (22.0-34.5)	63.3 (56.7-74.9)	180 (154-210)	482 (409-555)	1340 (1010-1660)	3480 (2210-5100)	1456
Gender								
Males	179 (157-204)	28.4 (23.8-35.4)	54.7 (48.3-64.1)	154 (121-191)	523 (400-621)	1430 (1150-2090)	3480 (2270-4330)	1214
Females	178 (154-206)	28.0 (21.8-32.1)	65.0 (57.6-80.2)	174 (145-205)	425 (356-482)	977 (825-1340)	2230 (1330-4100)	1322
Race/ethnicity								
Mexican Americans	181 (163-201)	30.2 (25.2-38.1)	66.8 (56.6-77.4)	174 (150-205)	441 (410-510)	1250 (893-1410)	1720 (1410-2450)	813
Non-Hispanic blacks	322 (278-373)	56.1 (48.3-73.2)	127 (111-143)	306 (256-350)	789 (588-996)	1880 (1340-2460)	3600 (2100-4900)	603
Non-Hispanic whites	152 (134-173)	27.2 (20.1-31.1)	52.3 (44.6-61.4)	133 (110-157)	366 (312-450)	977 (796-1340)	2470 (1430-4330)	907

after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-ethyl phthalate levels were found to be lower for ages 6-11 years than for the other two age groups (trending in an opposite direction from mono-butyl, mono-benzyl, and mono-ethylhexyl phthalates, all of which decreased with increasing age). Levels in females were higher than levels in males. Non-Hispanic blacks had higher levels than non-Hispanic whites or Mexican Americans. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Table 63. Mono-ethyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	163 (148-179)	33.0 (29.1-35.8)	64.7 (57.5-73.5)	141 (132-155)	360 (313-411)	898 (762-1150)	1950 (1460-2730)	2536
Age group								
6-11 years	92.6 (74.2-116)	29.7 (24.9-34.9)	45.6 (33.6-57.7)	79.4 (61.2-121)	165 (124-208)	341 (219-559)	625 (365-784)	328
12-19 years	142 (120-168)	29.8 (27.0-33.5)	50.7 (41.4-57.9)	122 (86.2-168)	361 (279-495)	879 (676-1260)	1550 (907-2030)	752
20 years and older	179 (161-199)	34.5 (29.1-39.1)	75.6 (66.3-83.6)	154 (139-170)	390 (338-452)	1010 (810-1440)	2170 (1670-3490)	1456
Gender								
Males	141 (124-159)	27.6 (22.6-33.1)	48.9 (40.3-60.8)	120 (106-138)	324 (268-391)	996 (761-1420)	1940 (1460-2900)	1214
Females	187 (167-209)	42.7 (34.7-51.7)	81.4 (73.4-94.8)	157 (142-182)	377 (333-453)	821 (719-1150)	1920 (1100-3410)	1322
Race/ethnicity								
Mexican Americans	164 (145-186)	36.3 (29.2-41.5)	63.4 (53.6-77.9)	154 (136-175)	382 (323-469)	814 (692-886)	1330 (1010-1860)	813
Non-Hispanic blacks	208 (183-237)	46.7 (38.4-54.7)	86.4 (69.8-108)	196 (164-232)	443 (363-528)	1030 (762-1700)	1880 (1290-2450)	603
Non-Hispanic whites	149 (133-167)	31.8 (26.5-34.7)	58.6 (50.7-68.6)	128 (113-139)	313 (249-376)	834 (663-1200)	1950 (1420-3350)	907

Mono-butyl phthalates

CAS No. 131-70-4

Metabolites of dibutyl phthalates (CAS No. 84-74-2) and benzylbutyl phthalate (CAS No. 85-68-7)

Dibutyl phthalates (di-n-butyl, di-iso-butyl) are industrial solvents or additives used in many consumer products such as nail polish, cosmetics, some printing inks, pharmaceutical coatings, and insecticides. People exposed to dibutyl phthalates will excrete mono-butyl phthalates (n-butyl, iso-butyl) in their urine. Exposure to benzylbutyl phthalate will also result in small amounts of mono-butyl phthalates appearing in the urine (Anderson et al. 2001). The amount of mono-butyl phthalates is an indicator of how much contact with dibutyl phthalates has occurred.

Workplace air standards for external exposure to dibutyl phthalate have been established (NIOSH, ACGIH). Generally, dibutyl phthalates have low acute toxicity. Dibutyl phthalates have not been completely classified with respect to its carcinogenicity (U.S. EPA, IARC, NTP). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported here are similar to or slightly lower than those reported for a non-random subsample

Table 64. Mono-butyl phthalates

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	24.6 (22.7-26.6)	5.70 (4.80-6.40)	12.6 (11.0-14.3)	26.0 (24.2-28.5)	51.6 (46.9-56.1)	98.6 (90.7-114)	149 (126-167)	2541
Age group								
6-11 years	41.4 (35.8-47.8)	15.1 (11.0-16.9)	23.0 (19.1-27.2)	40.0 (33.7-50.3)	75.5 (59.0-94.5)	124 (92.8-166)	163 (114-306)	328
12-19 years	36.0 (31.9-40.5)	11.9 (8.10-14.8)	20.0 (17.3-25.4)	36.1 (31.7-42.3)	67.7 (56.7-76.1)	119 (94.3-146)	165 (133-209)	752
20 years and older	21.6 (19.7-23.6)	4.70 (4.20-5.90)	10.3 (9.40-11.6)	23.0 (20.7-25.0)	46.1 (39.7-51.3)	95.0 (81.1-107)	142 (118-161)	1461
Gender								
Males	22.0 (20.2-24.0)	5.70 (4.70-6.60)	11.3 (9.90-13.0)	23.1 (21.0-25.2)	43.1 (36.9-49.3)	83.9 (71.3-96.2)	115 (96.2-142)	1215
Females	27.3 (24.4-30.4)	5.80 (4.10-7.60)	13.8 (11.6-16.4)	30.0 (26.1-33.1)	59.5 (52.0-65.6)	119 (100-143)	167 (145-218)	1326
Race/ethnicity								
Mexican Americans	23.4 (20.8-26.4)	5.10 (4.40-6.10)	11.8 (10.1-13.9)	26.3 (23.6-29.2)	48.1 (41.8-54.6)	92.2 (71.9-107)	116 (101-136)	814
Non-Hispanic blacks	37.0 (32.5-42.1)	10.3 (8.00-14.4)	22.2 (18.2-24.6)	38.7 (34.5-42.6)	78.2 (63.1-86.7)	117 (104-149)	167 (143-192)	603
Non-Hispanic whites	21.8 (19.8-24.0)	5.00 (4.20-6.30)	10.6 (9.60-12.5)	23.1 (20.4-26.1)	45.9 (39.1-51.6)	90.2 (75.4-102)	138 (112-161)	911

from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-butyl phthalate levels were higher for ages 6-11 years than for the other two age groups and higher in those 12-19 years than in people aged 20 years and older. Levels in females were higher than in males. It is unknown whether differences between ages or sexes represent differences in exposure, body-size relationships, or metabolism.

A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested that higher levels of mono-butyl phthalates in urine were associated with less education.

Table 65. Mono-butyl phthalates (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	22.4 (21.1-23.8)	7.74 (6.79-8.63)	12.8 (11.7-14.2)	21.9 (20.3-23.4)	38.9 (36.1-41.1)	68.3 (61.7-74.9)	97.5 (84.4-113)	2541
Age group								
6-11 years	41.9 (37.2-47.4)	16.7 (10.6-22.0)	27.8 (23.3-32.1)	38.9 (32.5-49.6)	65.7 (54.9-80.0)	107 (80.0-162)	159 (106-196)	328
12-19 years	24.3 (22.0-26.8)	9.80 (7.68-11.5)	15.4 (13.2-17.0)	23.6 (21.6-26.3)	37.6 (32.6-42.2)	62.3 (53.7-72.1)	88.1 (69.6-139)	752
20 years and older	20.4 (19.0-21.9)	7.08 (5.95-8.18)	11.7 (10.9-13.0)	19.5 (18.4-21.0)	34.9 (31.2-38.2)	62.4 (56.0-68.6)	91.0 (78.3-112)	1461
Gender								
Males	17.3 (16.0-18.7)	6.54 (5.70-7.46)	10.2 (9.57-11.3)	17.0 (15.5-18.7)	28.6 (25.8-32.0)	49.1 (42.4-53.9)	63.6 (57.3-76.7)	1215
Females	28.6 (26.5-30.9)	10.6 (8.54-11.7)	17.3 (15.9-18.6)	28.6 (26.2-30.4)	50.6 (44.9-54.2)	84.3 (73.5-97.6)	131 (98.5-153)	1326
Race/ethnicity								
Mexican Americans	21.2 (18.9-23.9)	6.98 (5.23-8.50)	12.9 (10.2-14.5)	20.0 (18.2-22.8)	40.1 (33.7-44.0)	63.6 (57.6-70.1)	81.6 (73.9-100)	814
Non-Hispanic blacks	23.9 (21.6-26.4)	8.51 (6.90-9.92)	13.9 (12.4-16.0)	25.0 (20.7-27.9)	42.2 (36.8-49.3)	69.6 (62.6-83.9)	94.4 (76.7-108)	603
Non-Hispanic whites	21.3 (19.6-23.2)	7.16 (6.03-8.54)	12.1 (11.1-13.9)	20.5 (18.9-22.9)	36.4 (32.3-39.6)	67.1 (58.1-74.9)	97.6 (81.4-135)	911

Mono-benzyl phthalate

CAS No. 2528-16-7

Metabolite of benzylbutyl phthalate (CAS No. 85-68-7)

Benzylbutyl phthalate is an industrial solvent and additive used in products such as adhesives, vinyl-flooring products, sealants, car-care products and to a lesser extent, some personal-care products. People exposed to benzylbutyl phthalate will excrete mono-benzyl phthalate in their urine. The amount of mono-benzyl phthalate is an indicator of how much contact with benzylbutyl phthalate has occurred.

Workplace air standards for external exposure have not been established (OSHA, ACGIH) for benzylbutyl phthalate. Generally, benzylbutyl phthalate has low acute toxicity. It is classified as a possible human carcinogen (U.S. EPA) but considered not classifiable by IARC and incompletely classified by NTP. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris.

Concentrations reported here are similar to or slightly lower than those reported in a non-random subsample from NHANES III participants (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric

Table 66. Mono-benzyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	15.3 (14.0-16.8)	2.80 (2.30-3.50)	6.90 (6.00-8.20)	17.0 (15.3-18.6)	35.3 (32.8-38.9)	67.1 (56.8-80.7)	103 (90.3-123)	2541
Age group								
6-11 years	39.4 (34.7-44.8)	9.40 (7.20-13.9)	22.1 (17.2-28.1)	40.3 (34.2-48.6)	82.0 (59.9-90.0)	128 (98.1-214)	214 (107-464)	328
12-19 years	25.6 (22.7-29.0)	6.30 (5.10-8.10)	13.4 (10.8-15.9)	28.3 (23.0-33.6)	51.1 (43.7-58.5)	87.9 (71.2-106)	125 (100-160)	752
20 years and older	12.4 (11.3-13.8)	2.20 (1.80-2.80)	5.80 (5.10-6.40)	13.8 (12.3-15.3)	28.9 (26.5-31.9)	52.0 (45.3-56.8)	86.3 (61.3-103)	1461
Gender								
Males	16.2 (14.5-18.0)	3.40 (2.40-4.40)	8.00 (6.00-9.20)	17.7 (15.5-19.4)	35.4 (32.8-38.6)	69.4 (59.9-85.8)	108 (94.0-139)	1215
Females	14.6 (13.0-16.3)	2.40 (1.90-3.10)	6.10 (5.20-7.60)	16.0 (14.2-19.2)	35.8 (31.0-41.0)	63.7 (54.7-74.1)	103 (86.3-116)	1326
Race/ethnicity								
Mexican Americans	13.9 (11.9-16.4)	2.40 (1.70-3.50)	6.30 (5.20-7.80)	15.7 (12.1-18.0)	33.0 (26.7-37.2)	67.5 (55.9-80.6)	98.3 (80.6-150)	814
Non-Hispanic blacks	23.0 (20.0-26.5)	5.10 (3.70-6.40)	12.3 (10.0-13.7)	23.0 (20.0-27.0)	49.3 (40.1-56.1)	94.0 (79.1-130)	138 (115-233)	603
Non-Hispanic whites	14.3 (12.7-16.0)	2.50 (1.90-3.20)	6.50 (5.30-8.10)	16.1 (14.3-18.5)	33.9 (30.7-37.5)	58.7 (52.0-71.5)	103 (73.4-116)	911

mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-benzyl phthalate levels were found to be higher for the 6-11-year-old group than for the other two age groups, and levels in the 12-19-year-old group were higher than levels in the group aged 20 years and older. Females had higher levels than males.

It is unknown whether differences between ages or genders represent differences in exposure, body-size relationships, or metabolism. A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested that a lower income and a lower level of education were associated with higher urinary concentrations of mono-benzyl phthalate.

Table 67. Mono-benzyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	14.0 (13.0-15.0)	4.41 (3.64-4.75)	7.57 (6.89-8.45)	13.3 (12.7-14.6)	25.1 (23.5-27.0)	50.1 (41.4-59.6)	77.4 (69.2-88.7)	2541
Age group								
6-11 years	40.0 (34.1-46.9)	12.5 (9.32-18.3)	21.7 (19.4-27.2)	38.4 (30.3-50.6)	73.2 (58.2-89.4)	104 (89.4-142)	142 (99.8-173)	328
12-19 years	17.3 (15.5-19.3)	6.01 (5.39-7.09)	10.6 (8.68-12.3)	17.0 (14.9-19.7)	28.3 (24.9-32.3)	49.7 (41.4-61.7)	69.3 (50.1-81.9)	752
20 years and older	11.8 (10.9-12.7)	3.59 (3.16-4.42)	6.67 (6.09-7.46)	12.1 (11.3-12.8)	20.1 (18.5-23.1)	34.3 (30.5-40.8)	57.2 (42.5-73.9)	1461
Gender								
Males	12.7 (11.6-13.9)	3.81 (3.26-4.67)	6.58 (5.94-7.61)	12.3 (11.5-13.1)	23.7 (21.5-26.1)	44.5 (36.6-53.3)	73.5 (57.0-89.4)	1215
Females	15.3 (14.1-16.5)	4.84 (4.38-5.72)	8.73 (7.52-9.63)	14.7 (13.3-16.1)	25.9 (24.1-29.2)	56.4 (41.4-64.3)	80.0 (64.8-99.1)	1326
Race/ethnicity								
Mexican Americans	12.6 (11.2-14.3)	3.49 (3.00-4.21)	6.55 (5.49-7.77)	11.9 (10.7-13.5)	24.1 (20.8-28.7)	46.5 (40.9-54.2)	68.1 (55.2-98.8)	814
Non-Hispanic blacks	14.8 (13.0-16.9)	4.93 (3.96-5.88)	7.81 (7.12-8.75)	13.6 (11.7-15.6)	26.9 (21.9-32.4)	55.5 (38.7-77.2)	86.8 (64.4-99.8)	603
Non-Hispanic whites	14.0 (12.7-15.3)	4.42 (3.52-4.77)	7.66 (6.47-8.75)	13.4 (12.6-15.2)	25.2 (23.2-27.3)	53.3 (38.6-65.6)	77.9 (69.1-90.3)	911

Mono-cyclohexyl phthalate

CAS No. 7517-36-4

Metabolite of dicyclohexyl phthalate (CAS No. 84-61-7)

Dicyclohexyl phthalate is used primarily in research laboratories. Human exposure to this phthalate would not be expected to be widespread. People exposed to dicyclohexyl phthalate will excrete mono-cyclohexyl phthalate in their urine. The amount of mono-cyclohexyl phthalate is an indicator of how much contact with dicyclohexyl phthalate has occurred.

Workplace air standards for external exposure have not been established for dicyclohexyl phthalate. Generally, dicyclohexyl phthalate has low acute toxicity. It has not been completely classified as to its carcinogenicity (U.S. EPA, IARC, NTP).

Only 7.0% of the NHANES 1999-2000 subsample had detectable levels. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.7 µg/L detection limit).

Table 68. Mono-cyclohexyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.50)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.70 (1.00-3.80)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.70 (1.00-2.40)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.70)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.70)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (.900-1.20)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	.900 (<LOD-1.40)	911

< LOD means less than the limit of detection, which is 0.9 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 69. Mono-cyclohexyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.00 (2.60-3.33)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.82 (1.54-6.00)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.67 (1.33-1.82)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.14 (1.67-3.00)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.28 (2.86-3.53)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.43 (1.03-1.88)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.00 (2.61-3.53)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Mono-2-ethylhexyl phthalate

CAS No. 4376-20-9

Metabolite of di-2-ethylhexyl phthalate (CAS No. 117-81-7)

Di-2-ethylhexyl phthalate is primarily used to produce flexible plastics, mainly polyvinyl chloride, which is used for many home and garden products, food containers, toys, and blood-product storage and delivery systems. Concentrations in plastic materials may reach 40% by weight. Di-2-ethylhexyl phthalate has been removed from or replaced in most children's toys and food packaging in the United States. Other sources of exposure include food, such as milk, cheese, and fish, with fatty foods containing higher levels. People exposed to di-2-ethylhexyl phthalate will excrete mono-2-ethylhexyl phthalate in their urine.

Generally, di-2-ethylhexyl phthalate has low acute toxicity. The metabolite, mono-ethylhexyl phthalate, is considered to be a more toxic compound than the parent phthalate. Liver toxicity and testicular toxicity have been observed in animal studies at high doses and chronic doses. Recently, the U.S. Food and Drug Administration (FDA) considered the amounts of di-2-ethylhexyl phthalate or mono-2-ethylhexyl phthalate (the latter is formed *in situ* in blood from di-2-ethylhexyl phthalate) received from medicinal delivery systems to be below

Table 70. Mono-2-ethylhexyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	3.43 (3.19-3.69)	< LOD	1.20 (<LOD-1.40)	3.20 (2.90-3.50)	7.60 (6.80-8.20)	14.8 (13.6-17.3)	23.8 (19.2-28.6)	2541
Age group								
6-11 years	5.12 (4.25-6.16)	< LOD	2.40 (1.80-3.10)	4.90 (3.80-5.50)	11.1 (7.70-13.7)	19.0 (13.7-36.1)	34.5 (14.7-130)	328
12-19 years	3.75 (3.30-4.27)	< LOD	1.60 (1.30-1.80)	3.70 (2.90-4.50)	8.10 (6.30-9.60)	15.0 (11.5-20.2)	22.8 (19.5-26.3)	752
20 years and older	3.21 (2.95-3.49)	< LOD	< LOD	3.00 (2.60-3.30)	7.20 (6.30-8.10)	14.2 (12.2-16.5)	22.4 (16.8-27.8)	1461
Gender								
Males	3.68 (3.26-4.15)	< LOD	1.40 (1.20-1.80)	3.40 (2.80-4.10)	8.00 (6.80-9.10)	16.0 (13.8-20.2)	25.3 (18.3-38.3)	1215
Females	3.21 (2.93-3.51)	< LOD	1.20 (<LOD-1.40)	3.00 (2.70-3.50)	7.00 (5.90-8.10)	13.5 (11.4-15.2)	21.6 (17.2-26.0)	1326
Race/ethnicity								
Mexican Americans	3.49 (3.13-3.88)	< LOD	1.50 (<LOD-1.70)	3.50 (3.00-3.70)	7.00 (5.90-8.60)	13.3 (10.7-19.1)	23.9 (16.4-29.3)	814
Non-Hispanic blacks	4.82 (4.07-5.71)	< LOD	2.50 (1.70-3.00)	5.10 (4.10-5.90)	9.40 (7.80-11.2)	19.5 (14.6-24.5)	29.2 (19.5-39.3)	603
Non-Hispanic whites	3.16 (2.89-3.46)	< LOD	< LOD	2.70 (2.50-3.10)	7.30 (6.30-8.20)	14.4 (12.2-16.6)	22.4 (16.5-29.3)	911

< LOD means less than the limit of detection, which is 1.2 µg/L.

thresholds likely to cause injury in adults. However, in lifesaving instances, in which neonates would receive exchange blood transfusions, relatively higher exposures might occur (http://www.fda.gov/cdrh/ost/dehp-pvc.pdf).

Workplace air standards for external exposure to di-2-ethylhexyl phthalate are generally established (OSHA, ACGIH). It is classified as a probable human carcinogen by the U.S. EPA, reasonably anticipated to be a human carcinogen by NTP, but considered not classifiable by IARC. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported here are similar to those reported in a non-random subsample from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-ethylhexyl phthalate levels were higher for ages 6-11 years than for the other two age groups. It is unknown whether differences between ages represent differences in exposure, body-size relationships, or metabolism. A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested slightly higher levels in urban populations, low-income groups, and males.

Table 71. Mono-2-ethylhexyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	3.12 (2.92-3.35)	< LOD	1.52 (1.37-1.69)	3.08 (2.81-3.31)	5.88 (5.38-6.27)	10.8 (9.47-12.9)	18.5 (14.0-23.9)	2541
Age group								
6-11 years	5.19 (4.17-6.45)	< LOD	2.56 (2.05-3.33)	5.37 (4.00-6.29)	9.11 (7.51-12.1)	21.6 (11.6-41.9)	41.9 (13.5-86.2)	328
12-19 years	2.53 (2.21-2.89)	< LOD	1.22 (1.03-1.46)	2.31 (2.11-2.60)	5.83 (4.42-6.27)	9.63 (7.78-11.3)	12.1 (11.0-17.3)	752
20 years and older	3.03 (2.80-3.29)	< LOD	< LOD	2.98 (2.72-3.26)	5.55 (4.90-6.04)	10.0 (8.60-12.9)	17.5 (13.4-22.1)	1461
Gender								
Males	2.89 (2.58-3.24)	< LOD	1.33 (1.19-1.52)	2.76 (2.37-3.18)	5.58 (4.67-6.11)	10.3 (8.90-13.5)	21.6 (13.3-28.4)	1215
Females	3.36 (3.12-3.63)	< LOD	1.82 (1.63-1.99)	3.33 (3.00-3.66)	6.15 (5.55-6.76)	11.1 (9.33-13.5)	16.3 (12.9-23.7)	1326
Race/ethnicity								
Mexican Americans	3.16 (2.77-3.60)	< LOD	1.54 (1.36-1.79)	3.15 (2.62-3.74)	5.88 (4.92-7.20)	11.6 (10.0-12.6)	15.7 (12.6-23.1)	814
Non-Hispanic blacks	3.11 (2.68-3.61)	< LOD	1.68 (1.31-1.98)	3.13 (2.62-3.37)	5.84 (4.66-7.06)	10.2 (8.77-13.6)	18.4 (11.8-35.2)	603
Non-Hispanic whites	3.09 (2.80-3.41)	< LOD	< LOD	3.08 (2.67-3.48)	5.87 (5.14-6.67)	10.6 (8.74-13.7)	20.0 (13.1-27.7)	911

< LOD means less than the limit of detection (see previous table).

Mono-n-octyl phthalate

CAS No. 5393-19-1

Metabolite of dioctyl phthalate (CAS No. 117-84-0)

Dioctyl phthalate is used primarily to produce flexible plastics. People exposed to dioctyl phthalate will excrete mono-n-octyl phthalate in their urine. The amount of mono-n-octyl phthalate is an indicator of how much contact with dioctyl phthalate has occurred.

Workplace air standards for external exposure are established (OSHA) for dioctyl phthalate. Generally, dioctyl phthalate has low acute toxicity. It has not been completely classified with respect to its carcinogenicity (U.S. EPA, IARC, NTP). Information on external exposure and health effects is available from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations documented in this *Report* are close to the detection limit. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.9 µg/L detection limit) and 95th percentile levels similar to this *Report*.

Table 72. Mono-n-octyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	1.60 (1.20-2.10)	2.90 (2.20-3.40)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.00 (1.10-2.90)	3.20 (2.00-4.10)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	1.60 (.900-2.40)	2.80 (2.20-3.70)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	1.50 (1.10-2.00)	2.90 (1.90-3.50)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	1.60 (1.10-2.00)	2.80 (2.10-3.40)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	1.40 (.900-2.20)	3.10 (2.10-3.70)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.40)	1.50 (1.20-3.30)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	1.80 (1.00-2.80)	3.00 (2.20-3.70)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	1.50 (1.00-2.40)	3.00 (2.20-3.60)	911

< LOD means less than the limit of detection, which is 0.9 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 73. Mono-n-octyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	2.40 (2.00-2.73)	3.51 (3.00-4.00)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.22 (1.54-3.75)	3.75 (1.90-10.3)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	1.49 (1.30-1.69)	1.82 (1.58-3.00)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	2.56 (2.07-2.86)	3.47 (3.08-4.00)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	1.82 (1.54-2.05)	2.52 (2.00-3.16)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	2.95 (2.50-3.60)	4.00 (3.42-5.37)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	1.82 (1.46-2.61)	3.16 (2.86-3.94)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	1.36 (1.05-1.88)	2.18 (1.43-3.42)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	2.60 (2.07-3.08)	3.60 (3.16-4.49)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Mono-isononyl phthalate

Metabolite of di-isononyl phthalate (CAS No. 28553-12-0)

Di-isononyl phthalate is actually a mixture of phthalates with alkyl side chains of varying length (C8, C9, and C10). Di-isononyl phthalate is primarily used to produce flexible plastics and has been used to replace di-2-ethylhexyl phthalate in some plastics. Di-isononyl phthalate is now widely used in such products as children's toys, flooring, gloves, food-packing material, drinking straws, and garden hoses. People exposed to di-isononyl phthalate will excrete mono-isononyl phthalate in their urine. The amount of mono-isononyl phthalate is an indicator of how much contact with di-isononyl phthalate has occurred.

Workplace air standards for external exposure have not been established for di-isononyl phthalate. Generally, di-isononyl phthalate has low acute toxicity in animals. Although considered an animal carcinogen, di-isononyl phthalate has not been completely classified as to human carcinogenicity (U.S. EPA, IARC, NTP).

Concentrations documented in this *Report* are close to the detection limit. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.8 µg/L detection limit) and 95th percentile levels similar to this *Report*.

Table 74. Mono-isononyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.50 (<LOD-11.9)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	5.70 (<LOD-22.5)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.30 (<LOD-9.60)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.10 (<LOD-11.9)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.90 (1.20-15.6)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.50 (<LOD-6.80)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.40 (<LOD-2.70)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	6.80 (<LOD-15.6)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.50 (<LOD-15.7)	911

< LOD means less than the limit of detection, which is 0.8 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 75. Mono-isononyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.29 (3.16-6.76)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	6.00 (2.84-14.2)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.94 (1.36-6.32)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.62 (3.33-7.79)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.24 (2.22-8.91)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.29 (3.33-5.47)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.51 (2.86-4.94)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.26 (1.88-8.57)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	5.00 (3.23-9.07)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.